STAR GEAR SYSTEM WITH LUBRICATION CIRCUIT AND LUBRICATION METHOD THEREFOR

TECHNICAL FIELD

The present invention relates to epicyclic gear trains and particularly to an epicyclic gear train configured as a star gear system and having effective, simple means for supplying lubricant to selected components of the gear system and for recovering used lubricant.

BACKGROUND OF THE INVENTION

Epicyclic gear trains are used to reduce rotational speeds in various types of machinery. Depending on the speed reduction ratio desired, an epicyclic gear train can be configured as either a planetary system or a star system. A planetary system includes a central sun gear and a set of planet gears rotatably mounted on a gear carrier by bearings. The planet gears are circumferentially distributed about the periphery of the sun gear so that the planet gears mesh with the sun gear. A mechanically grounded, internally toothed ring gear circumscribes and meshes with the planet gears. Input and output shafts extend from the sun gear and gear carrier respectively. In operation, the input shaft rotatably drives the sun gear, compelling each planet gear to rotate about its own axis and, because the ring gear is mechanically grounded, causing the planet gears to orbit the sun gear. The planet gear orbital motion turns the carrier, and hence the output shaft, in the same direction as the input shaft.

A star system is similar to the above described planetary system except that the gear carrier is mechanically grounded, the ring gear is rotatable and the output shaft extends from the ring gear. Because the carrier is grounded, the “planet” gears cannot orbit the sun and therefore are referred to as star gears. In operation, the input shaft rotatably drives the sun gear, compelling each star gear to rotate about its own axis. The rotary motion of the star gears turns the ring gear, and hence the output shaft, in a direction opposite that of the input shaft.

An epicyclic gear train, whether configured as a planetary system or a star system, also has a lubrication system to lubricate and cool the gear teeth and bearings and to remove used lubricant so that it can be reconditioned (cooled, filtered, de-aerated) and reused. It is desirable to remove the used lubricant as completely and quickly as possible, otherwise the gears continually agitate the residual lubricant. Agitation of the residual lubricant degrades the power transmission efficiency of the gear system and elevates the lubricant temperature, making it more difficult to cool the lubricant to render it suitable for repeated use as a heat transfer medium. If the gear train is a component of an aircraft engine, degraded efficiency is unacceptable because it reduces aircraft range and/or payload. The problem of elevated lubricant temperature can be addressed with larger, higher capacity heat exchangers. However larger heat exchangers are unacceptable because they contribute undesirable weight and consume precious space on board the engine or aircraft.

U.S. Pat. No. 5,472,383 discloses a lubricant supply and recovery system for a planetary gear system. Noteworthy features of the system include a set of lubricant spray bars 32 intermediate each pair of planet gears 10, a set of interplanet baffles 80 each having a trough 82, and a set of collection channels 56. In operation, the spray bars 32 direct lubricant jets 34, 36 toward the sun and planet gears 8, 10. Most of the lubricant 34 passes through the sun/planet mesh. Much of the lubricant that passes through the sun/planet mesh is urged axially outwardly by the gear mesh and directly enters the collection channels 56. The balance of the lubricant that passes through the sun/planet mesh, along with lubricant reflected from the sun gear, is centrifuged into the nearby baffle trough 82, urged through outlets 84 in the planet carrier and finally deposited in the nonrotating collection channels 56. Meanwhile, the planet gears 10 carry lubricant 36 radially outwardly and into the planet/ring mesh. Lubricant expelled from the planet/ring mesh then enters the collection channels 56. Concurrently, pressurized lubricant enters the narrow bearing annulus (unnumbered) defined by the outer surface 44 of each journal bearing 16 and the inner surface 46 of the corresponding planet gear 10. Lubricant discharged from the bearing annuli enters the collection channels 56. Lubricant collected by the channels 56 enters a drain line 62, which conveys the lubricant to the lubrication system coolers, filters and de-aerators.

Despite the merits of the above described planetary lubrication system, it suffers from at least five shortcomings when applied to a star system. First, it relies on the centrifugal forces arising from carrier rotation to evacuate used lubricant. These forces are absent in the star system because the gear carrier is mechanically grounded. Second, the disclosed planetary system suffers from the complexity of two lubricant circuits, one to serve the planet gear journal bearings and one to serve the gear meshes. Both circuits are necessary. The gear lubrication circuit is necessary because the bearing lubricant, upon exiting the bearing annuli, is centrifuged away from the sun/planet mesh and so is unavailable to lubricate that mesh. The bearing lubrication circuit is necessary because the gear lubricant, after having been discharged from the spray bars, cannot be locally repressurized and introduced into the bearing annuli. Although the two circuits may share certain components (e.g. coolers, pumps, filters and de-aerators) other components (e.g. supply lines, spray bars) are unshared and introduce unwelcome complexity. Third, the presence of the dual lubricant circuits dictates that sufficient lubricant be available to concurrently supply both circuits, a distinct disadvantage in aircraft applications where space is at a premium and excess weight is always undesirable. Fourth, because the bearing lubricant cannot serve the gear meshes and vice versa, lubricant must be supplied in parallel to both the bearings and the gear meshes. As a result, a greater quantity of lubricant enters the gear system than would be the case if the bearings and gears were lubricated in series. The excess lubricant can exceed the lubricant evacuation capacity of the gear system thereby increasing lubricant residence time. The increased residence time provides additional opportunity for lubricant agitation and the concomitant loss of transmission efficiency and increased lubricant temperature described above. Fifth, the bearing lubricant and gear lubricant typically originate from a common source. This makes it impractical to customize the lubricant temperature to optimally satisfy the requirements of both the bearing annulus, which requires relatively cool lubricant, and the gear meshes, which benefit from warmer lubricant.

What is needed is a simple lubrication system for supplying lubricant to both the star gear bearings and the gear meshes in a star configured epicyclic gear train and for quickly and effectively evacuating used lubricant.

SUMMARY OF THE INVENTION

According to one aspect of the invention, a star configured epicyclic gear train includes a set of inter-star baffles for constraining the flow of lubricant and a lubricant circuit that